JoTT Communication 3(4): 1637–1655

An inventory of the chiropteran fauna of Himachal Pradesh, northwestern India with some ecological observations

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Date of publication (online): 26 April 2011
Date of publication (print): 26 April 2011
ISSN 0974-7907 (online) | 0974-7893 (print)

Editor: Malcolm Pearch

Manuscript details:
Ms # o2409
Received 22 February 2010
Final received 15 March 2011
Finally accepted 29 March 2011

Citation: Saikia, U., M.L. Thakur, M. Bawri & P.C. Bhattacherjee (2011). An inventory of the chiropteran fauna of Himachal Pradesh, northwestern India with some ecological observations. *Journal of Threatened Taxa* 3(4): 1637–1655.

Author Contribution: US conducted the field survey, identification of specimens and wrote the paper. MLT helped writing the paper and also accompanied in some field trips. MB helped in getting certain literature and helped in analyzing the results. PCB provided guidance in planning the field survey and also helped writing the mss.

For **Author Details** and **Acknowledgements** see end of this article.

Abstract: A chiropteran inventory of Himachal Pradesh, northwestern India is presented. Based on field observation and the study of museum collections and published literature, the occurrence of 28 species within 14 genera and five families is affirmed. The study also provides observations on ecology and biology of selected species, and ecological, zoogeographical and conservation aspects of the chiropteran fauna of Himachal Pradesh are also discussed. Considering the lack of studies on the bat fauna of Himachal Pradesh, it is expected that systematic and intensive field surveys will refine significantly our knowledge of diversity and distribution of Chiroptera in the state.

Keywords: Chiroptera, distribution, Himachal Pradesh, inventory, locality records.

INTRODUCTION

The state of Himachal Pradesh lies in the northwestern Himalaya between 30°22'44"–33°12'40"N and 75°40'55"–79°04'20"E and encompasses an area of 55,673km^2. The state has been divided into four distinct parallel physiographic zones, namely Shiwalik Himalaya, Lesser Himalaya, Greater Himalaya and Trans-Himalaya covering around 10.54% of the Himalayan land mass. The Shiwalik Himalaya (up to an elevation of 1500m) represent the southernmost zone, extending from northwest to south, 40–60 km wide and covering the districts of Sirmour, Solan, Bilaspur, Hamirpur, Una and parts of Chamba and Kangra. The Lesser Himalaya (about 80km wide) run from north of the Shiwalik and parallel to the great Himalayan range. This zone encompasses the districts of Shimla, Mandi and parts of the districts of Chamba, Kullu, Kangra and Sirmour. The Great Himalayan ranges lie just north of the Chandrabhaga River in Lahaul-Spiti and contain peaks with an elevation in excess of 6000m. This zone covers the Pangi region of Chamba District and certain portions of Kullu and Kinnaur districts. The Trans-Himalayan region, comprising Lahaul and Spiti valleys and parts of the district of Kinnaur, is characterised by extreme cold, low precipitation and lack of vegetation and is often referred to as cold desert (Rodger & Panwar 1988).

Abbreviations: AMNH - American Museum of Natural History, New York; BB - Breadth of braincase; C^1-C^1 - Width across upper canines; CBL - Condylo-basal length; CCL - Condylo-canine length; CM^3 - Length of the maxillary tooth-row; CM_3 - Length of mandibular tooth-row; E - Ear length; FA - Forearm length; FMNH - Field Museum of Natural History, Chicago; GTL - Greatest length of skull; HARC - High Altitude Regional Centre; HB - Head body length; HF - Feet length; M - Mandible length; M^3-M^3 - Width across upper molars; NZC - National Zoological Collection; TB - Length of tibia; TL - Tail length; Tr - Length of tragus; ZSIK - Zoological Survey of India, Kolkata; ZSIS - Zoological Survey of India, Solan; ZW - Zygomatic width.

Himachal Pradesh has an elevation range of 350–6,975 m. At lower elevations, four seasons: winter (December–February), summer (March–June), monsoon (July–September) and post monsoon (October–November) are recognised, with seasonal individuality decreasing with elevation. In higher alpine zones temperatures remain low throughout the year with subzero temperatures during the winter months. The state has an estimated forest cover of 17.15% of the total geographical area (Joshi et al. 2001). Along the foothills, vegetation is dominated by tropical forest of *Acacia* and *Zizyphus* or deciduous Sal (*Shorea robusta*) forest. Within an elevation range of 500–1800 m, subtropical forest of *Terminalia, Albizzia* or pure chir-pine (*Pinus roxburghii*) is found. Forest type between 1500–3000 m can be divided into moist temperate and dry temperate. Moist temperate forest is dominated by various species of oak (*Quercus* spp.), Deodar (*Cedrus deodaria*), Blue Pine (*Pinus wallichiana*) and *Rhododendron* sp. The dry temperate forest is characterised by species including *Quercus* sp. and *Pinus gerardiana*. Sub-alpine forest in the state is composed of birch (*Betula utilis*) and fir (*Abies spectabilis*) or scrub of *Rhododendron campanulatum* and *Juniperus communis*. Between the tree line and the snow line, dry alpine pastures of *Caragana* sp., *Lonicera* sp., *Festuca* sp., and *Artemisia* sp. are present.

The small mammalian fauna of Himachal Pradesh, and Chiroptera in particular, have received relatively little recent study compared to other vertebrate groups. The first report pertaining to the Chiroptera of Himachal Pradesh was that of Dobson (1873) who described *Vespertilio murinoides* (later synonymised with *Myotis blythii*) from the Chamba area of the state (erstwhile Punjab). Some information on diversity and distribution of bat fauna of the area is available from the past accounts of Blanford (1888–1891), Allen (1908), Dodsworth (1913), Thomas (1915) and Lindsay (1927). Blanford (1888–1891), in his "Fauna of British India", reported a few species of bats from the political boundary of present Himachal Pradesh, including *Myotis muricola* from Dalhousie and Shimla and *Barbastella leucomelas* from Shimla. Allen (1908) reported *Rhinolophus ferrumequinum*, *Scotophilus kuhlii* and *Scotoecus pallidus* from Koolloo valley (Kullu valley). Dodsworth (1913) recorded seven species of bats, namely *Pteropus giganteus, Rhinolophus ferrumequinum tragatus, Nyctalus montanus, N. labiatus, Myotis muricola, M. blythii* and *Pipistrellus coromandra* from Shimla and the adjoining hill region. Thomas (1915) reported *Myotis formosus* from Dharamsala and *M. blythii* from Shimla. Lindsay (1927) reported the collections made during the Mammal Survey of India organised by The Bombay Natural History Society and recorded seven species of bats from Himachal Pradesh, namely *Pteropus giganteus* from Kotla (Kullu District, erstwhile Kangra District) and Gopalpur (Kangra District), *Rhinolophus ferrumequinum tragatus* from Manali (Kullu District), *Pipistrellus javanicus* (*babu* in Lindsay) from Gopalpur (Kangra District), *Nyctalus noctula* (*labiatus* in Lindsay 1927) from Kangra (Kangra District) and Sissu (Lahaul and Spiti District), *Nyctalus leisleri* from Chamba (Chamba District), *Myotis mystacinus* (*muricola* in Lindsay, 1927) from Chirot, Pattan Valley (Lahaul and Spiti District) and *Myotis muricola* (*caliginosus* in Lindsay, 1927) from Chatri (Chamba District) and Samayala from Kangra valley (Kangra District). Besides these, a few occasional species records from the state also exist and these include *Plecotus auritus* (Bhat et al. 1983) and *Murina tubinaris* (Das 2003). Of late, a few more species have been added to the Chiropteran fauna of Himachal Pradesh (Saikia et al. 2004). However, there remains no consolidated account of the Chiroptera of Himachal Pradesh. A perusal of published information on the mammalian fauna of Himachal Pradesh reveals a varying number of bat species occurring in the state from five (Mahajan & Mukherjee 1974), eight (Mehta & Julka 2002) to 23 (Chakraborty et al. 2005). A review of the comprehensive work of Bates & Harrison (1997) reveals that 19 species of bats exist in the state. The latest account of the mammalian fauna of Himachal Pradesh by Chakraborty et al. (2005) includes some bat species (e.g. *Rhinopoma hardwickii, Hipposideros fulvus, Kerivoula picta, Eptesicus serotinus, Hesperotenus tickelli* etc.) that need confirmation as the authors do not mention the source of authentication of the same (voucher specimens etc.). Das (1986, 2003) includes Himachal Pradesh within the distributional range of *Rhinolophus rouxii*, a taxon which, in the northern part of its range (which includes Himachal Pradesh), is now referable to *R. sinicus* (see Thomas 2000). Bates & Harrison (1997), referring to Chakraborty (1983), report *Otonycteris hemprichii* from the Nagrota area

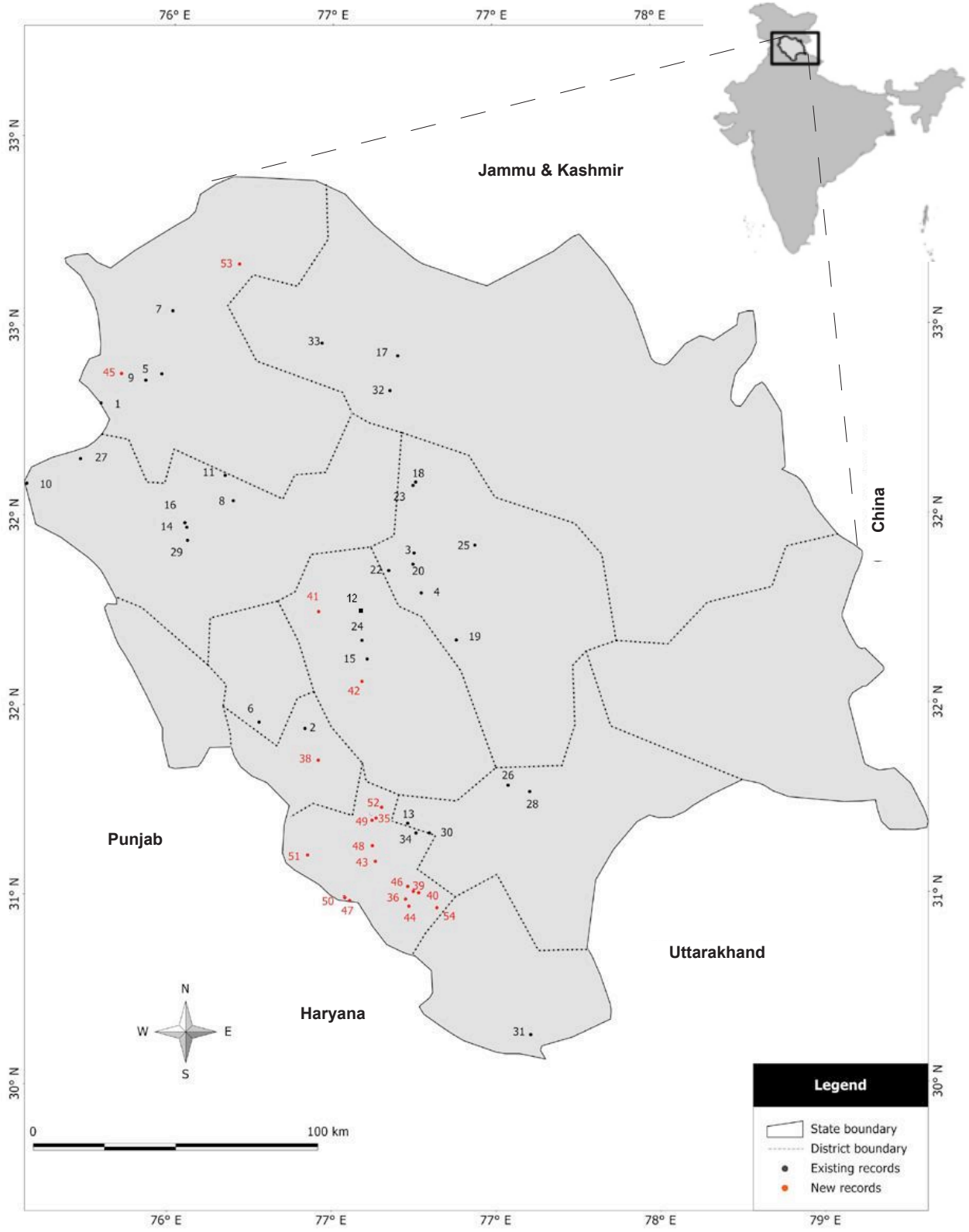

Figure 1. Map of Himachal Pradesh showing locality records for bats (district boundaries are provisional)
1 - Bakloh, 2 - Ballu at Ghumarwin, 3 - Bandrol, 4 - Bhunter, 5 - Chamba, 6 - Chakmoh, 7 - Chatri, 8 - Dadh, 9 - Dalhousie, 10 - Damtal, 11 - Dharamsala,12 - Drang, 13 - Ghanatti, 14 - Gopalpur, 15 - Gutkar, 16 - Kangra, 17 - Keylong, 18 - Kothi, 19 - Kotla, 20 - Kullu, 22 - Kullu Valley, 23 - Manali, 24 - Mandi, 25 - Manikaran, 26 - Narkanda, 27 - Nurpur, 28 - Ratandi in Baghi, 29 - Samayala, 30 - Shimla, 31 - Simbalbara, 32 - Sissu, 33 - Thirot, 34 - Tottu, 35 - Arki, 36 - Barog Tunnel,38 - Bilaspur, 39 - Brewery, 40 - Chambaghat, 41 - Dharampur, 42 - Dodour near Nehr Chowk, 43 - Gambhar, 44 - Happy valley, 45 - Kalatop, 46 - Karool hill, 47 - Kot Beja, 48 - Kunihar, 49 - Lutru cave, 50 - Majothu, 51 - Nalagarh, 52 - Shalaghat, 53 - Shaur, 54 - Solan.

of Himachal Pradesh but this locality is in Jammu and Kashmir (between Jammu and Udhampur on NH 1A). Accordingly, the above species are excluded from the present inventory. In view of the scattered nature of published information and the ambiguity regarding diversity and distribution of the bat fauna of Himachal Pradesh, this paper seeks, inter alia, to collate available information and to present an up to date account of the same.

METHODS

The present account is based largely on the first author's collections and field observations mostly in the Shiwalik area of Himachal Pradesh during 2004–2006. Earlier collections of Chiroptera held at the High Altitude Regional Centre, Zoological Survey of India, Solan were examined and published literature on the bat fauna of Himachal Pradesh was reviewed. The locality records and elevations mentioned in the Gazetteer are based on the first author's field observations, collection localities of specimens at the Zoological Survey of India at Solan and Kolkata (vide Ghosh 2008), and published records. The geographic locations and elevations of collection or observation localities during field surveys were recorded using a Garmin™ 12 GPS unit. For museum specimens and published records where geographic co-ordinates were not available, approximate co-ordinates and elevations were determined from toposheets and from Google Earth (www.googleearth.com). For comparison of diversity along elevation gradients, intervals were established as follows: 500–1000 m, 1001–1500 m, 1501–2000 m, 2001–2500 m, 2501–3000 m. Elevations below 500m and above 3000m were not taken into account since there are no bat records beyond these ranges in Himachal Pradesh. Species were assumed to occur in all elevation intervals in between their distributional extremes as established from their maximum and minimum elevation records. Those species marked with an asterisk are represented in the collections of HARC, ZSI Solan and have been examined. Species identifications follow Bates & Harrison (1997) and detailed taxonomic measurements of studied specimens are provided. Common names follow Bates & Harrison (1997). Conservation status in South Asia is pursuant to Molur et al. (2002).

Species account

Sub-order: Megachiroptera

Family: Pteropodidae

1. *Rousettus leschenaulti* (Desmarest, 1820)*

Fulvous Fruit Bat

New material: Female, 29.v.2004, 3km upstream of Gambhar Bridge, Solan District, M24, (HARC, ZSIS)

Locality records: ?Ballu, Bilaspur District (c. 700m) (Bhat et al. 1983); Bandrol, Kullu District (Bhat et al. 1983); Dadh, Kangra District (1080m) (Bhat et al. 1983); Gambhar, Solan District (780m) (present study); Gutkar, Mandi District (710m) (Bhat et al. 1983); Mandi, Mandi District (1050m) (Bhat et al. 1983); Sooma , Kullu District (1400m) (Bhat et al. 1983).

Ecological notes: A colony of this bat was located in a natural cave approximately 8m. in length on the bank of a stream (Gambhar) in Solan District. At the end of May, around 250 individuals were seen roosting inside the cave. On entering the cave, a strong smell of fermenting fruit was detected. Probably this smell emanated from undigested or partly digested fruit pulps regurgitated by the bats and scattered over the cave floor. A similar strong smell in *Rousettus* roosts has been reported by Roberts (1977) in Pakistan. The bats were observed to be very noisy and some individuals kept flying from one place to another in the cave at all times. A few individuals were caught by setting a mist net in front of the cave mouth and then disturbing the colony but most of them were able to avoid the net by deft manoeuvring. Along with Microchiroptera, the megachiropteran genus *Rousettus* has developed vocal echolocation (*Eonyteris* echolocates by wing clapping (Gould 1988)) producing signals by clicks of the tongue (Jones & Holderied 2007; Raghuram et al. 2007) enabling them to orient, forage and roost in low light situations. Despite the rudimentary nature of this echolocating mechanism, spatial resolution of the system is apparently comparable to Microchiroptera in some respects (Holland et al. 2007). A study by researchers in southern India has revealed that the obstacle avoidance efficiency of the echolocatory mechanism in *R. leschenaulti* is as good as microchiropteran bats (Raghuram et al. 2007). However, it was not clear whether echolocation had any role in avoidance of the mist nets set in front of the cave. It was noted that all the captured adult

individuals were females while one was a juvenile male (FA-68mm and incomplete dentition). Whether this indicates the existence of a maternal colony is not clear because the juvenile did not appear to be a dependent young. However, sexual segregation in this species had been reported in Madhya Pradesh during March, June and July (Khajuria 1979).

Local people reported that the bats do not use the cave site during winter but reappear in spring. This probably indicates seasonal movement in search of food since no significant fruiting occurs during the winter season in the area where the cave is located. Brosset (1962) noted that in the area of Bombay, these bats periodically abandon their roosts for a few months and he believed non availability of food to be the reason.

Conservation status: Least Concern

2. *Pteropus giganteus* Brunnich, 1782*
Indian Flying Fox

Locality records: Bilaspur, Bilaspur District (530m) (present study); Dharampur, Mandi District, (630m) (present study); Dodour near Nehr Chawk, Mandi District (c.760m) (present study); Gopalpur, Kangra District (Lindsay 1927); Kotla, Kullu District (940m) (Lindsay 1927); Kulu, Kullu District (Ferrar 1934; Paul et al. 2009); Kunihar, Solan District (960m) (present study); Nalagarh, Solan District (c.600m) (present study); Nurpur, Kangra District (c.590m) (present study).

Ecological notes: Three big and three small colonies of this species were observed during the study period. One colony was located at Kunihar in a few Siris (*Albizia lebbeck*) trees near a check dam. About 200 individuals were observed in the month of July, 2005 but on a visit in January, 2006, the number was estimated to be approximately 120 individuals, suggesting seasonal variations of colony size and local migration. Another colony was located at Bilaspur Town on the bank of Sutlej River. The colony size estimated in the month of November was about 500 individuals and they were roosting in five *Orix siris* trees. The third colony was observed near Dharampur, Mandi District roosting in a large, unidentified tree: the number of bats was estimated to be around 150 during May, 2006. A few pups attached to the mother were also observed. The population trend of *P. giganteus* in Himachal Pradesh is not known. In 2005, under the auspices of the Chiroptera Conseravtion and Information Network of South Asia (CCINSA), project "PteroCount" was initiated to count and monitor *P. giganteus* roosts throughout South Asia on a voluntary basis. Under this project, so far 16 roosts of this species have been reported from various parts of Himachal Pradesh (Molur 2009).

Local migration of flying foxes has been reported in Himachal Pradesh (Paul et al. 2009). In Kullu, a colony of fruit bats has been regularly observed to roost in poplar trees from the last week of April to October before migrating to an unknown place (Paul et al. 2009). Flying foxes cause considerable damage to the fruit orchards of Himachal Pradesh. Fortunately, local people are not antagonistic towards them and, despite some damage to their fruit crops, live in harmony with them.

Conservation status: Least Concern

Sub-order: Microchiroptera
Family: Megadermatidae
3. *Megaderma lyra* E. Geoffroy, 1810
Greater False Vampire

Locality record: Damtal, Kangra District (c. 850m) (Ghosh 2008) (NZC, ZSIK 17123); Kangra, Kangra District (Sinha 1980).

Conservation status: Least Concern

Family: Rhinolophidae
4. *Rhinolophus ferrumequinum* (Schreber, 1774)*
Greater Horseshoe Bat

New material: Male, 02.v.2004, Barog Tunnel, Solan District, M21 (HARC, ZSIS); male, 30.v.2004, Lutru Cave, Arki, Solan District, M32 (HARC, ZSIS).

Locality records: Barog Tunnel, Solan District (1560m) (present study); Chakmoh, Hamirpur District (c.760m) (Ghosh 2008); Chamba, Chamba District (c.1000m) (Chakraborty 1977); Ghannati, Shimla District (c.1640m) (Ghosh 2008); Koolloo Valley (Kullu Valley), Kullu District (Allen 1908); Lutru Cave near Arki, Solan District (1550m) (present study); Mandi, Mandi District (c.1050m) (Ghosh 2008); Manali, Kullu District (1950m) (Lindsay 1927); Shimla, Shimla District (2100m) (Dodsworth, 1913; Bates & Harrison 1997); Solan Town, Solan District (1500m) (present study); Tottu, Shimla District (c.1900m) (Ghosh 2008).

Ecological notes: This species has been observed to roost in Barog tunnel, a railway tunnel on the historic Kalka-Shimla track, which is 1140m long. In the month of May, four specimens were collected throughout the length of the tunnel. They were seen hanging from the wall of the tunnel in small numbers and their total number was estimated to be 90–100 individuals. The species was not recorded during two subsequent visits to the tunnel within the following four months although small groups of *Rhinolophus affinis* (collected earlier at the site) and possibly another rhinolophoid (darker than *R. affinis*) were observed. Whether *R. ferrumequinum* use the tunnel as a seasonal roost or whether the bats simply evaded notice because of smaller numbers was not determined. Although the bats seemed to be indifferent to railway traffic, they became active and flew away when approached by humans. This species has also been observed roosting in small numbers (c. 15 individuals) in a subterranean cave on a hillock at Arki in Solan District in the last week of May with some individuals carrying pups. One male pup collected had forearm length of 44mm and weighed 11g. The pelage of the collected specimen was long and soft and light brownish throughout.

Conservation status: Vulnerable

5. *Rhinolophus sinicus* (Anderson, 1905)*
Chinese Horseshoe Bat

New material: Female, 14.v.2004, Happy Valley, Solan District, M27 (HARC, ZSIS)

Locality records: Happy Valley, Solan District (1550m) (present study).

Ecological notes: A single specimen was caught in a butterfly net on 14.v.2004 while hanging from the roof of a natural cave near Solan Town (1550m). It was carrying a suckling, the age of which was estimated to be approximately 15–20 days (8g in weight) on the basis that no bats were observed carrying young on a visit that took place 21 days before the collection date. Accordingly, the parturition period of the species in this area would appear to be in the last week of April or the first week of May. Seven or eight other individuals were also observed carrying pups and this may indicate sexual segregation of lactating females as reported by Allen (1938). Pelage of the collected specimen was soft, silky and chocolate brown dorsally with a paler belly.

Taxonomic remarks: Bates & Harrison (1997) recognised two subspecies of *R. rouxii* in India namely *R. r. rouxii* and *R. r. sinicus* and referred Himalayan populations to *R. r. sinicus*. Based on mitochondrial DNA analysis, Thomas (2000) elevated *sinicus* to specific status. The external and cranial measurements of the single specimen studied fall within the measurement ranges for both *R. rouxii* and *R. sinicus* provided by Thomas (2000). However, the noseleaf and sella structure correspond to those of *R. sinicus* described by Thomas (2000).

Conservation status: Near Threatened

6. *Rhinolophus affinis* Horsefield, 1823*
Intermediate Horseshoe Bat

New material: Male, 09.iv.2004, Kot Beja, Solan District, M28 (HARC, ZSIS); female, 15.ix.2004, Happy Valley, Solan District, M31 (HARC, ZSIS); female, 31.iv.2004, Barog Tunnel, Solan District, CW1 (HARC, ZSIS).

Locality records: Barog Tunnel, Solan District (1560m) (present study); Happy Valley, Solan District (1550m) (present study) and Kot Beja, near Kasauli, Solan District (1100m) (present study).

Ecological notes: A roost of approximately 10 individuals was observed in a cave near Solan. The cave was dark and humid: water was observed dripping from the roof and the cave mouth was surrounded by vegetation. The site was found to be inhabited by two other species, namely *R. ferrumequinum* and *M. mystacinus,* at different times. Another individual was caught while entering a house adjacent to a cattleshed. The collected specimens had silky fur and were dull brown throughout.

Conservation status: Least Concern

7. *Rhinolophus luctus* Temminck, 1835*
Wooly Horseshoe Bat

New material: Female, 27.v.2004, Arki, Solan District, M20 (HARC, ZSIS); male, 27.v.2004, Shalaghat, Solan District, M48 (HARC, ZSIS).

Locality records: Arki, Solan District (900m) (present study); Shalaghat, Solan District (1200m) (present study).

Ecological notes: A lone individual of this species was captured on 27.v.2004 from a dark corner of a dilapidated temple, which was surrounded by thick lantana bushes. The specimen was in an advanced stage of pregnancy with a foetus weighing 10g. The

parturition period of this species in this area appears to occur during the month of June (Saikia et al. 2004). Another individual of the same species was observed hanging from the wall of a narrow cave at Shalaghat in Solan District. Bates & Harrison (1997) reported that this species normally roosts in pairs but our observations suggest that it also roosts solitarily. Pelage of the collected specimens was distinctively long, woolly and dark brown throughout.

Conservation status: Near Threatened

8. *Rhinolophus lepidus* (Blyth, 1854)
Blyth's Horseshoe Bat

Locality records: Drang, Mandi District (c.780m) (Ghosh 2008) (NZC, ZSIK 24881); Kullu, Kullu District (c.1200m) (Ghosh 2008) (NZC, ZSIK 24882).

Conservation status: Least Concern

Family: Hipposideridae
9. *Hipposideros armiger* Hodgson, 1835*
Great Himalayan Leaf-nosed Bat

New material: Male, 18.ix.2004, Karool hill, Solan District, M33 (HARC, ZSIS).

Locality record: Karool hill near Solan Town, Solan District (2200m) (present study).

Ecological notes: A single specimen was collected from a cavesite on the top of a hill surrounded by *Quercus* forest near Solan Town. The cave had about ten individuals of this species and was shared by another two species *viz. Myotis mystacinus* and *M. blythii*. The emergence time of this species recorded in mid September was 1840 hr and the whole colony came out within 10 minutes; this was earlier than the other two species sharing the cave. The lone specimen collected had long, smooth and overall dark brown fur on the back with a comparatively paler belly.

Conservation status: Least Concern

Family: Vespertilionidae
10. *Miniopterus schreibesrsii* (Kuhl, 1819)*
Schreiber's Long Fingered Bat

New material: Female, 02.v.2004, Barog Tunnel, Solan District, M22 (HARC, ZSIS); female, 16.iv.2004, Brewery Tunnel, Solan District, M30 (HARC, ZSIS); female, 15.iv.2004, Chambaghat, Solan District, CW3 (HARC, ZSIS).

Locality records: Barog Tunnel, Solan District (1560m) (present study); Brewery Tunnel, Solan District (1480m) (present study); Chambaghat, Solan District (1450m) (present study).

Ecological notes: This species was observed roosting in Barog tunnel in large numbers (about 2000). Individuals were in close proximity to each other and were pressed together in several layers. All those specimens collected in the month of May were female. Accordingly, the formation of female colonies cannot be ruled out although this is not corroborated by the observations of Brosset (1962) at Mahabaleshwar. This species was also observed roosting in another railway tunnel about 10km away from Barog, where they were seen inside holes in the walls in groups of 4–5. In this case, both male and female specimens were collected from the same hole. Of the six individuals examined, five had a dark brown dorsal pelage with a lighter venter. One individual had a much darker, almost black, dorsum, which would indicate the occurrence of colour variations within the same population.

Conservation status: Least Concern

11. *Myotis mystacinus* (Kuhl, 1819)*
Whiskered Bat

New material: 2 females, 14.v.2004, Happy Valley, Solan District, M25, M35 (HARC, ZSIS); 2 males, 18.ix.2004, Karool hill, Solan, CW36, CW37 (HARC, ZSIS).

Locality records: Chirot in Pattan Valley (possibly Thirot), Lahaul & Spiti (2910m) (*muricola* in Lindsay, 1927); Happy Valley, Solan District (1550m) (present study); Karool Hill near Solan Town, Solan District (2200m) (present study).

Ecological notes: On 14 May 2005, individuals of this species were seen hanging from the ceiling of a cave in a tight group of over 100 individuals. From this group, about 20 specimens were captured using a butterfly net. Five individuals were taken as voucher specimens and the rest were released after morphological measurements were taken and the sex of the individual determined. All individuals were found to be female. Among the five specimens, three were carrying foetuses at various stages of development (weighing 0.23–0.83 g). In previous visits to the site and afterwards, we were unable to observe any such congregations of this species. This may indicate the formation of an exclusive maternal

colony during the breeding season. Considering the stages of foetal development, the parturition period of this species in this area is presumed to be June to July. In India, formation of maternal colonies by this species has not been reported but Roberts (1977) did report maternal colonies from Dunga Gali and Shogran area of northeast Pakistan. However, Bates & Harrison (1997) opined that all records of *M. mystacinus* from Pakistan are misidentified specimens of *M. muricola*. Another population of about 50 individuals of this bat was observed in a cave atop a hill at an elevation of 2200m near Solan Town.

Taxonomic remarks: This species is externally similar to *M. muricola*. However, the dark brown dorsum and silvery grey hair tips on the ventral areas of the collected material (discernable in fresh and alcohol preserved specimens) is distinctive of *mystacinus* (Bates & Harrison 1997).

Conservation status: Vulnerable

12. *Myotis blythii* (Tomes, 1857)*
Lesser Mouse-eared Bat

New material: Male, 18.ix.2004, Karool Hill, Solan District, M34 (HARC, ZSIS).

Locality records: Chamba, Chamba District (900m) (Dobson 1873); Dalhousie, Chamba District (c. 2000m) (Bates & Harrison 1997); Karool hill near Solan Town, Solan District (2200m) (present study); Shimla and neighbourhood, Shimla District (1820m) (Dodsworth 1913; Thomas 1915).

Ecological notes: a colony of approximately 100 individuals of this species was observed in a short and narrow cave in a hilltop (2200m), which it shared with *H. armiger* and *M. mystacinus*. It was seen hanging from the roof of the cave, mixing frequently with *M. myatacinus*. Interestingly, it maintained quite a distance from individuals of *H. armiger*. *M. blythii* was observed crawling on the roof of the cave using its feet and first digit to change position. Amongst the three species inhabiting the cave, this species emerges from the cave the latest and only after darkness has fallen fully. Pelage of the collected specimens was somewhat woolly in texture and beige brown dorsally.

Conservation status: Vulnerable

13. *Myotis siligorensis* (Horsefield, 1855)*
Himalayan Whiskered Bat

New material: Female, 05.iii.1973, Solan Town, Solan District, M38 (HARC, ZSIS).

Locality records: Solan Town, Solan District (1500m) (present study).

Remarks: The specimen at ZSIS was collected in the month of October, 1974 in Solan Town. The specimen lacks other details (e.g. habitat, method of collection). This species was not encountered during the present survey and appears to be rare in the study area. The alcohol preserved specimen is creamy white, which is probably the result of its long period of preservation. However, dark hair roots are still discernable. The species' identification was confirmed by the late Dr. P.K. Das.

Conservation status: Near Threatened

14. *Myotis formosus* (Hodgson, 1835)
Hodgson's Bat

Locality records: Dharamsala, Kangra District (*c.*1250m) (Thomas 1915); Drang, 17km north of Mandi, Mandi District (*c.*780m) (Ghosh 2008).

Conservation status: Least Concern

15. *Myotis muricola* (Gray, 1846)*
Nepalese Whiskered Bat

New material: Female, 18.ix.2010, Kalatop, near Dalhousie, Chamba District, M50 (HARC, ZSIS).

Locality records: Chatri, Chamba District (1800m) (*M. caliginosus* in Lindsay 1927); Dalhousie, Chamba District (c. 2042m) (Blanford 1888–1891; Khajuria 1953); Kalatop, Chamba District (2400m) (present study); Samayala, Kangra District (1500m) (*M. caliginosus* in Lindsay 1927); Shimla, Shimla District (c. 2000m) (Dodsworth 1913).

Ecological notes: A single specimen was collected from the verandah of the forest rest house at Kalatop in mid September. Two individuals were observed in the space between the wooden ceiling and some tin sheets. Local people report that during summer months, they can be seen roosting in large numbers there but that the species is not observed during winter months, the same indicating seasonal migration or hibernation. Dodsworth (1913) collected this bat from the porch of his bungalow in Shimla. He reported that the bat is very active during summer months and probably hibernates for a long period. The breeding period was reported to range between May and June in Shimla. The ventral fur of the Kalatop specimen has slightly paler hair tips and dark roots (not discernable in the

wet preserved specimen) in contrast to the silvery hair tips of the congeneric *mystacinus*.

Conservation status: Least Concern

16. *Pipistrellus tenuis* Temminck, 1840*
Indian Pygmy Bat

New material: Female, 08.iv.2005, Majutho, near Barotiwala Solan District, M37 (HARC, ZSIS).

Locality records: Bhunter, Kullu District (c. 1080m) (Ghosh 2008); Kullu Valley, Kullu District (FMNH 34147); Manikaran, Kullu District (c.1740m) (Ghosh 2008); Majothu near Barotiwala, Solan District (520m) (present study); Simbalbara Wildlife Sanctuary, Sirmour District (590m) (Sharma & Saikia 2009).

Ecological notes: Specimens of this bat were collected in a mist net set on the bank of a check dam and in the vicinity of human habitation at Majthu near Barotiwala in Solan District. This species is known to roost near human habitation. In Kerala, it has been collected beneath road bridges, from hollows of coconut trees and under the tiled roofs of houses (Madhavan 2000). Prakash (1962) comments that it is one of the first bats to make an appearance and reports the collection of three specimens between 1815 and 1830 hr in April (darkness was still to fall). Activity appeared to decrease as night set in. These bats were caught barely a metre above the embankment of the check dam, confirming the observations of Bhattacharyya (1985) that it hunts frequently close to the ground. This species was also observed and collected along the bank of a dry stream amidst mixed *Shorea robusta* forest in Simbalbara WLS in Sirmour district. The collected specimens had a dark brown dorsum and a distinctly lighter venter.

A prolific breeder, these bats have been reported to undergo parturition in four distinct cycles in southern India including one in March–April (Isaac et al. 1994). However, the female specimens collected in April in Himachal did not exhibit any breeding activity or show any sign of lactation (as evinced by diminutive mammary glands).

Taxonomic remarks: Bates & Harrison (1997) mention that it is not possible to distinguish *P. tenuis* and smaller individuals of *P. coromandra* by external characters alone in sympatric situations. The cranial measurements of the above specimens are significantly smaller than specimens of *P. coromandra* examined presently and fit well into the character matrix for *P. tenuis* given by Bates & Harrison (1997).

Conservation status: Least Concern

17. *Pipistrellus coromandra* (Gray, 1838)*
Coromandel Pipistrelle

New material: 2 females, 18.vii.2009, Shaur, Pangi Valley, Chamba District, M46, M48 (HARC, ZSIS).

Locality records: Bakloh, Chamba District (*c.*1330m) (Ghosh 2008); Narkanda, Shimla District (2470m) (Ghosh 2008); Shaur, Pangi Valley, Chamba District (2400m) (present study).

Ecological notes: Two individuals were caught with a butterfly net while foraging around a lamppost at Shaur in Pangi Valley, Chamba District. An active flyer, it can avoid a mist net very efficiently and no individuals could be caught in three sessions of netting in an area frequented by the species. This wariness of mist nets was noted by Chakraborty (1983). Feeding activity starts before darkness sets in fully and it continues for about 50–60 minutes, after which the bats disappear for some time before foraging is resumed. This pattern of feeding behaviour was observed until 2230 hr, after which time it became sporadic. Bhattacharyya (1985) reports that foraging continues throughout the night in this fashion. Dodsworth (1913) noted that this bat was very common in Shimla but disappeared during winter months, such absence being consistent with a period of hibernation. Gut content of a preserved specimen contained mostly undigested parts of moths and Dipterans.

Conservation status: Least Concern

18. *Pipistrellus javanicus* (Gray,1838)*
Javan Pipisterlle

New material: 2 females, 27.v.2004, Arki, Solan District, M23, M49 (HARC, ZSIS).

Locality records: Arki, Solan District (900m) (present study); Gopalpur, Kangra District (2700m) (*Pipistrellus babu* in Lindsay 1927) and Shimla, Shimla District (c. 2100m) (Siddiqi 1961; Bates & Harrison 1997).

Ecological notes: A few individuals were caught in a mist net set on the verandah of a house while foraging around a striplight. They were seen hunting actively in the early evening hours but could not be observed afterwards. These bats have also been observed often flying quite low around human settlements. The

specimens had a dark brown dorsal pelage and a fawn coloured venter.

Taxonomic remarks: Among the closely similar species of *Pipistrellus,* namely *P. tenuis, P. coromandra* and *P. javanicus,* there is significant overlapping of external measurements, making species assignment awkward. However, in the ascending order of *P. tenuis, P. coromandra* and *P. javanicus,* there is an increase in cranial measurements. The series of specimens assigned to *P. javanicus* have the greatest cranial measurements among the *Pipistrellus* specimens examined presently and conform well to the character matrix for the species by Bates & Harrison (1997).

Conservation status: Least Concern

19. *Pipistrellus dormeri* (Dobson, 1785)*
Dormer's Bat

New material: 2 females, 08.iv.2005, Majothu near Barotiwala, Solan District, M36, M47 (HARC, ZSIS); female, 17.ix.07, Solan Town, Solan District, CW 43 (HARC, ZSIS).

Locality record: Majothu, near Barotiwala, Solan District (520m) (present study); Solan Town, Solan District (1500m) (present study).

Ecological notes: These bats were caught in a mist net set on the bank of the same check dam where *P. tenuis* was collected. This species is known to drink water from ponds and lakes (Bates & Harrison 1997) and this drinking behaviour was also observed on that day. They were seen hovering over the water surface before making a swift descent to drink. Until 2100 hr, the bats were observed to forage over the water surface; similar foraging behaviour has been reported in some species of *Myotis* and *Pipistrellus* (Taylor 2006). In live specimens, the dorsal surface was clove brownish with streaks of silver whilst the ventral surface was significantly paler.

Conservation Status: Least Concern (LC)

20. *Pipistrellus ceylonicus indicus* (Dobson, 1878)
Kellart's Pipistrelle

Locality record: Ghanatti, Shimla District (c. 1640m) (Ghosh 2008) (NZC, ZSIK 24879).

Conservation status: Least Concern

21. *Scotophilus kuhlii* Leach, 1821*
Asiatic Lesser Yellow House Bat

New material: Male, 12.ix.1980, Solan Town, Solan District, M45 (HARC, ZSIS); female (1973), Solan Town, Solan District, M51 (HARC, ZSIS).

Locality record: Koolloo Valley (Kullu Valley), Kullu District (*Pachyotus temminckii* in Allen 1908); Solan Town, Solan District (1500m) (present study).

Ecological notes: The specimens at HARC were collected beneath a tin shed amidst human settlements on the periphery of Solan Town in 1973, indicating a perihuman dwelling habit of the species.

Dorsal areas of specimen M45 are chocolate brown although other parts of the specimen have faded owing to its long retention in alcohol. A few other alcohol preserved specimens are reddish brown dorsally and a little paler ventrally.

Conservation status: Least Concern

22. *Plecotus homochrous* Hodgson, 1847
Brown Long-eared Bat

Locality record: Ratandi, near Bagi, Shimla District (2700m) (Bhat et al. 1983).

Conservation status: Near Threatened

23. *Barbastella leucomelas* (Cretzschmar, 1826)
Eastern Barbastelle

Locality record: Shimla, Shimla District (*c.*2200m) (Blanford 1888-1891; Ghosh 2008 - NZC, ZSIK Reg. No.19324).

Conservation status: Near Threatened

24. *Scotoecus pallidus* Dobson, 1876
Desert Yellow Bat

Locality record: Koolloo Valley (Kullu Valley), Kullu District (*Scoteinus pallidus* in Allen 1908) (FMNH 34173, 34174; AMNH 54419, 54420).

Conservation status: Near Threatened

25. *Nyctalus noctula* (Schreber, 1774)
Noctule

Locality records: Kangra, Kangra District (c. 760m) (*N. labiatus* in Lindsay 1927; Bates & Harrison 1997); Mandi District (Chakraborty 1983); Sissu, (Lahaul and Spiti District) (3000m) (*N. labiatus* in Lindsay 1927); Shimla, Shimla District (2100m) (*N. labiata* in Dodsworth 1913).

Ecological notes: Dodsworth (1913) noted that this bat is a forest dwelling species that is found solitarily in natural crevices and holes of trees.

Conservation status: Least Concern

26. *Nyctalus leisleri* (Kuhl, 1890)
Leisler's Bat

Locality records: Chamba, Chamba District (1000m) (Lindsay 1927); Kothi, Kullu District (c. 2575m) (Bhat et al. 1983); Shimla, Shimla District (c. 2000m) (Bates & Harrison 1997).

Conservation status: Endangered

27. *Nyctalus montanus* (Barret-Hamilton, 1906)
Mountain Noctule

Locality record: Chamba, Chamba District (c. 1000m) (Bates & Harrison 1997); Shimla, Shimla District (2100m) (Dodsworth 1913).

Ecological note: Dodsworth (1913) collected this species from the roof of a bungalow in Shimla.

Conservation status: Near Threatened

28. *Murina tubinaris* (Scully, 1881)
Scully's Tube Nosed Bat

Locality record: Kalung (Keylong), Lahaul & Spiti District (c. 3000m) (AMNH 150088).

Remarks: Included after Das (2003), who reported the species on the basis of a specimen in the American Museum of Natural History. The female specimen was collected from Kalung in Lahul (Punjab) which obviously refers to Keylong in Lahaul and Spiti District of Himachal Pradesh (erstwhile Punjab State).

Conservation status: Near Threatened

DISCUSSION

The present checklist of bats recorded form Himachal Pradesh comprises 28 species of 14 genera from five families. Despite its small geographic area (1.76% of the total area of India), 25% of the chiropteran species known from India are represented in the state. The families Megadermatidae and Hipposideridae are represented by single species and the ubiquitous family Vespertilionidae includes 19 species. Whilst some of the species, such as those of the genus *Pipistrellus*, are common in many parts of the state, others, such as *Megaderma lyra, Scotecus pallidus, Murina tubinaris,* and *Myotis siligorensis*, are known only from a single museum specimen

Table 1. External measurements of the specimens of 16 species of bats from Himachal Pradesh examined presently

Species	n	HB	TL	HF	E	FA	TB	Tr
Pteropodidae								
Rousettus leschenaulti	1♀	98	17	17	23	80	32	-
Hipposideridae								
Hipposideros armiger	1♂	81	61	15.2	30	95	42	-
Rhinolophidae								
Rhinolophus ferrumequinum	2♀	55-58	33-34	11.5-12	20-23	57-62	24-26	-
R. sinicus	1♀	48	25	9	18	50	21	-
R. affinis	1♂1♀	50-55	24-25	9-10.5	17	53-65	24-24.5	-
R. luctus	1♂1♀	80-87	54	19-20	39-41	72-74	40	-
Vespertilionidae								
Miniopterus schreibersii	3♀	60-65	55-60	10	9-10.5	46-48.5	20-21	5-5.2
Myotis mystacinus	1♂3♀	42-43	36-37	7.2-7.5	13.8-14	35.2-36.5	14-16	6-7
Myotis muricola	1♀	40	37	6.3	13	35	13.1	4.9
M. blythii	1♂	61	52	13.5	16	59	27	8
M. siligorensis	1♀	32		6.3	8.7	33	10.7	-
Pipistrellus tenuis	2♀	37-37.5	29	5.5	8-8.2	27.5-28.5	11.9-12	3.4-4
P. coromandra	2♀	36-37	28-29	4.5-4.7	8.4-10	32.3-33	11.3-12.5	4-4.5
P. javanicus	2♀	40-44	32-34	5	11	32-33	12-13	4-5
P. dormeri	1♂1♀	45-51	35-40	7.5	11.2-12.5	35.2-37.1	14.5	4.5-5
Scotophilus kuhlii	1♂	-	42	9	11	43.2	17	4

Table 2. Cranial measurements of studied specimens from Himachal Pradesh

Species	n	GTL	CBL	CCL	CM^3	M^3–M^3	BB	PC	ZW	C^1–C^1	M	CM_3
Pteropodidae												
Rousettus leschenaulti	1♀	37.4	35.5	33.8	14	11	15.2	7.8	21	7	28.9	15.1
Hipposideridae												
Hipposideros armiger	1♂	32.8	29.8	28.6	12.8	13	12	5	18	8.3	22.8	14.1
Rhinolophidae												
Rhinolophus ferrumequinum	2♀	24.4–25.5	21.5–22.6	21.2–21.8	9.2–9.6	9.2–9.5	10–10.5	3.1	12.2–13	6.5–7.2	16.2–17.2	10–10.3
R. sinicus	1♀	21.4	19	18.4	8	8.4	9.4	2.1	11.2	5.5	14.2	8.6
R. affinis	1♂ 1♀	23.4–23.6	20.8	19.8–19.9	9–9.2	9–9.1	9.2–9.5	2.6–2.9	11.5–12	6.1–6.4	15.5–15.8	9.5–10.3
R. luctus	1♀	33.4	29.6	28	12.1	11	13.5	3.2	15.3	8.4	22.5	13
Vespertilionidae												
Miniopterus schreibersii	2♀	16.2–16.3	15.2–15.5	14.6–14.8	6	6.7–6.8	8–8.4	3.5–3.9	8.7–9	4.3–4.8	12–12.3	6.2–6.3
Myotis mystacinus	2♀	13.1–14	12.8–12.9	11.6–12.1	4.9–5.1	5–5.5	6.8	3.2–3.3	8–8.7	3.5–4	10–10.5	5.3–5.4
Myotis muricola	1♀	13.2	12.6	11.9	5	5.3	6.3	3.3	8.4	3.5	9.7	5.4
M. blythii	1♂	21.7	20	18.8	8.6	9	9.9	5.3	13.6	5.5	16	9.5
M. siligorensis	1♀	13.5	12.4	12	5	5.5	6.6	3.3	8.3	3.5	9.8	5.1
Pipistrellus tenuis	2♀	11.2–11.4	10.8–11	10.3–10.5	3.8–3.9	4.7–5	5.8–6.2	3.2–3.4	7.4	3.4–3.7	8–8.1	4–4.3
P. coromandra	1♀	12	11.5	11.1	4.1	5.3	6.2	3.4	7.8	3.7	8.5	4.5
P. javanicus	1♀	13.3	12.1	12	4.9	6	6.4	3.4	8.2	4.1	9.7	5
P. dormeri	2♀	15.1–16	13.9–14.9	13.5–14.4	5.2–5.6	6.5–7	7.2–7.4	4–4.3	9.1–10.4	4.8–4.9	11–11.2	5.6–6.1
Scotophilus kuhlii	1♂	18.1	–	15.9	6.2	7	8.5	4.8	11.5	5	13	6.9

collected many years ago. However, considering the lack of studies on bat fauna in this part of the western Himalaya, the apparent rarity of some species is more likely to be the result of undersampling than low incidence. For instance, the Greater False Vampire Bat *Megaderma lyra*, is a widespread and common species in many parts of its range and is found in a variety of biotypes (Bates & Harrison 1997; Molur et al. 2002). Intriguingly, it is known from Himachal Pradesh only by a single record and it has not been reported from neighbouring states of Punjab and Haryana. Brosset (1962) mentioned that this species appears to avoid hilly country and it is probable that the bat is absent in many parts of the state. It is possible, however, that the species is distributed in the Shiwalik foothills, which are contiguous with the plains of Punjab and Haryana, and that it has gone unnoticed because of poor sampling efforts. Only systematic and intensive surveys in prospective areas can establish whether this is the case.

By virtue of its location in the transitional zone between the Palaearctic and the Oriental realms, the chiropteran fauna of Himachal Pradesh shows an admixture of species from both regions. Of the 28 species of bat known from the state, 19 have an Oriental affinity, eight are Palaearctic, and one species, *Miniopterus schreibersii*, finds representation in both realms. *Nyctalus spp. Pipistrellus javanicus, Barbastella leucomelanos, Plecotus auritus*, *Rhinolophus ferrumequinum*, and *Myotis mystacinus* are some of the Palaearctic species (Roberts 1977; Corbet & Hill 1992; Horáček et al. 2000) occurring in Himachal Pradesh. These elements probably entered this region from Iran through Pakistan or down through the Himalayas from the Hindu Kush and Uzbekistan (Roberts 1977) during the late Tertiary. Species with Oriental affinities include *Pteropus giganteus*, *Megaderma lyra, Hipposideros armiger, Rhinolophus*

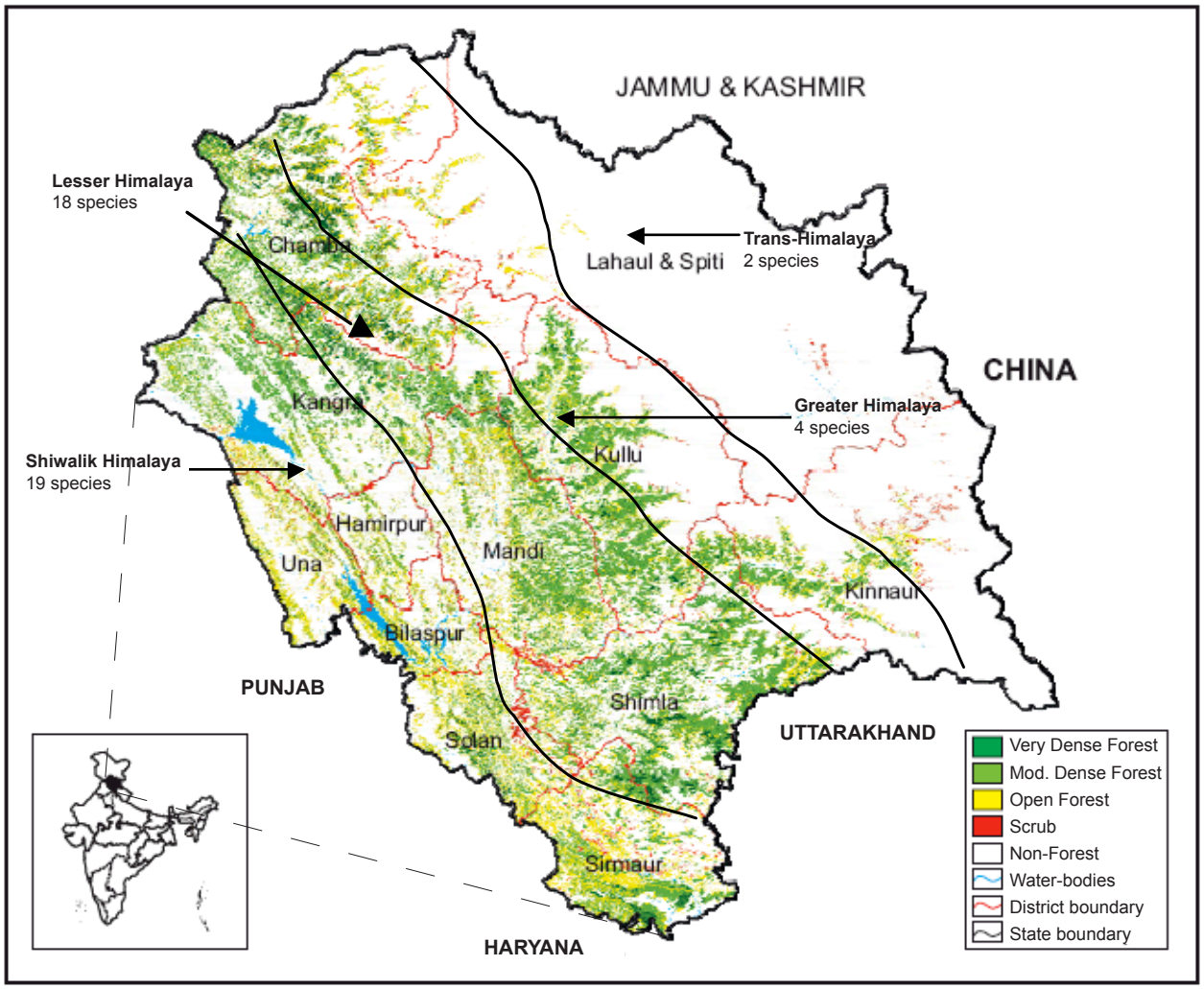

Figure 2. Species diversity of Chiroptera in the four physiographic zones of Himachal Pradesh (based on recorded localities). Boundaries of physiographic zones depicted in the map are provisional. (Vegetation cover map of Himachal Pradesh: www.mapsofindia.com)

sinicus, Rhinolophus luctus, and *Myotis siligorensis*. The possible route of invasion of oriental elements is along the Himalayas through northeastern India (Kurup 1966, 1974). No endemic species of bats have been reported from the state.

While most of the bats occurring in the state have a reasonably settled taxonomic status, the taxonomy of some species encountered in the area is uncertain or controversial. Many of them belong to species complexes where many morphologically indistinguishable forms are recognised as a single species but actually represent different species. For example, the *Miniopterus schreibersii* complex is found throughout the Palaearctic, Oriental, Afrotropic and Australian regions (Koopman 1994). There is extensive overlap of morphological variations within this complex and traditionally the complex is treated as a single species with several subspecies (Corbet 1978; Wilson & Reeder 1993). Applications of recent molecular techniques have revealed that the complex is a paraphyletic assemblage with several species (Appleton et al. 2004; Lanxiang et al. 2004). Thus, although this complex has a wide geographical distribution, member species can have smaller range bearing implications on their zoogeography. The same holds true for the widely distributed Palearctic *Myotis mystacinus* group, the taxonomy of which is one of the most complicated tasks of chiropteran systematics. The true nature of cryptic variations and whether they are single or a number of species is yet to be determined and the resolution of these matters lies far beyond the scope of traditional morphometric

taxonomy (Horáček et al. 2000).

Shiwalik (c.19 spp.) and the Lesser Himalaya (c.18 spp.) are the most diverse zones as far as Chiroptera is concerned (Fig. 2). This species richness is apparently a function of abundance of roosting sites along with other factors such as availability of food. Roosts are a critical resource for bats; their availability may limit the number and distribution of certain species (Humphrey 1975). By virtue of geology, mountainous terrain harbours large numbers of caves and caverns that provide ideal refugia for a significant number of bats. Bats adapt also to a variety of man-made structures, which may have a similar microclimate characteristic and may fulfil the same function as natural roosting places (Presetnik 2004). For this reason, several railway tunnels, especially on the century-old Kalka-Shimla track, have become favourite refugia for a large number of bats. Moreover, forest cover is an important factor for bats, providing resources for roosting, foraging, and drinking to a large number of species. For example, almost all North American bats rely on forest for survival (Taylor 2006). Forest cover is relatively intact in some parts of the Shiwaliks and the Lesser Himalayan zone and this may be a crucial factor in the survival of many forest-dependent bat species.

The trans-Himalayan areas of Himachal Pradesh comprising most parts of the districts Lahaul & Spiti and Kinnaur are characterised by scant rainfall and extremely low winter temperatures and, consequently, sparse vegetation. However, a few species of bats have adapted to such conditions. As homiothermic animals, bats are more cold tolerant than cold adapted. Species recorded from these parts of the state are *Myotis mystacinus* and *Murina tubinaris*. *Myotis mystacinus* has been recorded from warm tropical areas such as Hasimara in West Bengal to the trans-Himalayan cold desert of Ladakh (Bates & Harrison 1997), indicating wide ecological adaptability. Similar is the case of *M. tubinaris*, which is known from an elevation range of 615–2615 m (Bates & Harrison 1997). However, in these higher areas, food may be the limiting factor for distribution and abundance of bats since the growing season is too short to provide time for the gestation and rearing of young (Humphrey 1975). In addition, areas of high elevation present physiological challenges for mammals such as the difficulties of effective respiration in a rarified atmosphere and efficient thermoregulation in lower temperatures (Graham, 1990). Lower highland temperatures and oxygen concentration in the air may impede the upslope movement of lowland species, effectively putting a cap on species diversity. Nevertheless, it should be clear that present understanding of the geographical and ecological distribution of Chiroptera in Himachal Pradesh is inadequate and any generalisation must necessarily be crude.

For three species, Himachal Pradesh constitutes the westernmost point of their distribution. These species are *R. affinis, Hipposideros armiger*, and *Myotis siligorensis*. All these are Oriental species distributed in the Indian, Indochinese and Sundaic subregions of the Oriental realm (Corbet & Hill 1992) and the recorded westernmost point of their distribution is Solan in Himachal Pradesh (Saikia et al. 2004). As suggested by Kurup (1966, 1974), these elements invaded from the Indo-Chinese subregion through northeastern India and headed towards the northwestern parts of the narrow, wooded sub-Himalayan belt. Their failure to progress further west and south may have been caused by the prevailing drier conditions in those directions (the Thar Desert formed at that time).

The distribution of the chiropteran fauna of Himachal Pradesh exhibits a distinct elevation pattern; species diversity increases with elevation and reaches a maximum (21 spp.) in the 1001–1500 m zone and decreases thereafter. This is in accordance with a distribution trend having a mid-elevation peak (Rahbek 1995). Cumulative species richness increases sharply with elevation up to 1500m and thereafter increases moderately. Species richness is also a function of the transitional assemblages located between highland and lowland areas, which results in a complex pattern of species turnover. Interestingly, the percentages of

Table 3. Species richness, unique species richness and cumulative species richness of Chiroptera in five elevation zones of Himachal Pradesh.

Elevation range (m)	Unique Species richness	Species richness	Cumulative species richness	Percentage of unique species
500–1000	2	14	14	14.28
1001–1500	2	21	23	9.52
1501–2000	2	18	25	11.11
2001–2500	1	11	26	9.09
2501–3000	2	6	28	33.33

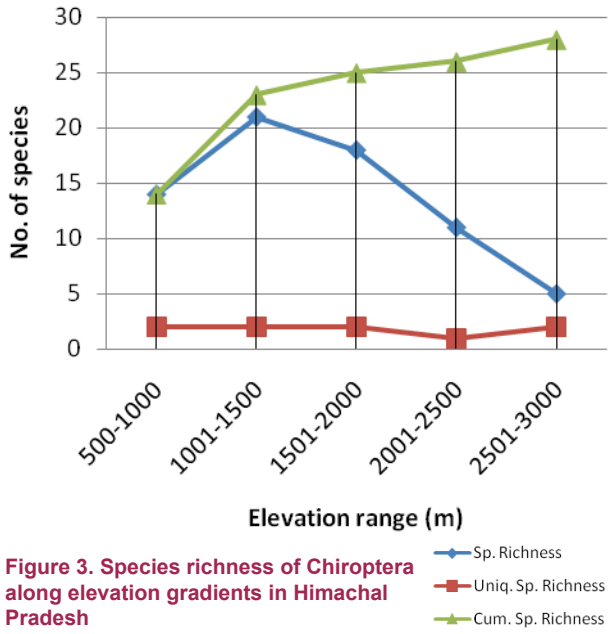

Figure 3. Species richness of Chiroptera along elevation gradients in Himachal Pradesh

unique species in all the zones excepting the highest zone are relatively low and are fairly comparable. This, in general, implies a broad distribution of fauna throughout the elevation ranges. No significant species boundary, where lowland species are replaced by highland forms and vice versa, can be drawn along the elevation gradients.

Occurrence of some bats at certain elevations can be the result of the ecological adaptations of particular species. For example, *Plecotus homochrous* (as *P. auritus*) has been recorded from an elevation of 2700m and, according to Bhat (1974), has never been encountered at lower elevations. Likewise, *P. dormeri* has been recorded at elevations around 500m and this species normally occupies the plains near human habitations. However, species such as *Myotis mystacinus, Nyctalus noctula, and Pipistrellus javanicus* have been recorded from lower areas to elevations nearing 3000m, indicating a broad ecological tolerance. In other parts of their ranges, these species are known also to occur throughout a broad range of elevation (Bates & Harrison 1997; Kaňuch & Krištín 2006).

Inter-specific associations

Many species of bats are known to share roosting sites with other species, often in close proximity. These associations may result from a limited number of roost sites or a convergence of roosting requirements (Kunz 1982). Although many of these associations are casual, there is evidence to suggest that, in some species, they may be essential (Dwyer 1968). Tuttle (1975) suggested that the reproductive success of some species may be augmented in situations where species are closely associated in roosts. Post natal growth and post flight survival of some species of bats increases with increased cave temperature. If colony sizes are too small to augment the cave temperature sufficiently, reproductive success may be affected severely (Tuttle 1976). Therefore, associations of small colonies of different species can help to maintain a warm cave environment. Lower predation risk from improved predator surveillance is another potential benefit of such associations. However, such benefits may be offset by disadvantages such as misdirected social behaviour (Bradburry 1977), competition for space, increased incidence of parasites and disease and greater risk of environmental stochastic events. During the field study, the following mixed species associations were observed.

(i) *Rhinolophus affinis, Rhinolophus* sp. and *Miniopterus schreibersii*: This association was observed in Barog railway tunnel. In this case, the unidentified Rhinolophid (which bore a resemblance to *R. sinicus*) and *R. affinis* were observed in close proximity but *M. schreibersii* was found to roost at some distance from both of these. However, this association appears to be casual and to result from the convergence of roosting requirements rather than obligatory, as a long, dark and humid tunnel could offer a suitable roosting microclimate for a large number of species.

(ii) *Rhinolophus sinicus* and *Myotis mystacinus*: This association was seen in May in a shallow, natural cave with an internal chamber of approx 10x6 ft. Both species were observed hanging from the ceiling of the internal chamber in small numbers (fewer than 30 individuals in total). One *R. sinicus* caught was carrying a suckling but it cannot be inferred that such physical associations increase the survival chances of the pups.

(iii) *Hipposideros armiger, Myotis mystacinus* and *M. blythii*: This association was observed within a 6–7 m long natural cave at an elevation of 2200m during September. *Myotis blythii* dominated the association with approx 100 individuals followed by ≥ 50 individuals of *M. mystacinus* and about 10 individuals

of *H. armiger*. Both *M. myatacinus* and *M. blythii* were observed hanging from the roof of the cave and intermixing frequently. *M. blythii* maintained a considerable distance (c.1.5m) from *H. armiger*, which was seen to move away when the former approached. It is possible that these associations, especially that of *M. blythii* and *M. mystacinus*, may have mutual benefits. According to a villager, these bats remain in the cave in winter, when the temperature is quite low. This association, therefore, might be of thermic benefit to the bats although further observations are required to substantiate this.

Species likely to occur in Himachal Pradesh

Although not reported so far, certain species of bats are likely to occur in the state. For example, many of the *Rhinolophus* species are more or less evenly distributed along the Himalayas from East to West. *Rhinolophus pearsonii, R. macrotis* and *R. pusillus* all occur along the Himalayan chain and the westernmost recorded locality in India of each is Mussoorie in Uttarakhand (Bates & Harrison 1997). Similarly, the widespread Short-nosed Fruit Bat *Cynopterus sphinx* has been recorded as far north as Jammu and Kashmir (Chakraborty 1983) with an apparent disjunction in Himachal Pradesh. Similarly, the Fulvous Leaf-nosed Bat *Hipposideros fulvus* Gray, 1838 is distributed widely across the Indian subcontinent with records in the adjacent states of Haryana (Siddiqi 1961) and Jammu & Kashmir (Saikia et al. 2006). Systematic and intensive surveys covering all physiographic zones of the state will add significantly to our understanding of bat diversity in Himachal Pradesh.

Conservation status

Of the 28 species of bat occurring in Himachal Pradesh, one is Endangered (*Nyctalus leisleri*), three are Vulnerable (*Rhinolophus ferrumequinum, Myotis blythii* and *M. mystacinus*), eight species are Near Threatened (*Rhinolophus sinicus*, *R. luctus*, *Myotis siligorensis*, *Plecotus homochrous*, *Barbastella leucomelas*, *Scotoecus pallidus*, *Nyctalus montanus* and *Murina tubinaris*) and 16 are Least Concern (Molur et al. 2002). The majority of taxa in the Least Concern category comprise several well-distributed *Pipistrellus* species together with a number of Vespertilionid and Rhinolophoid taxa. However, these categories apply largely to South Asia and the local population status of bat species in the state appears to vary to some extent. For example, both *Myotis blythii* and *M. mystacinus* have been recognised as Vulnerable on the basis of very small population sizes. However, our field observations suggest that the population sizes of these two taxa might not be very small in Himachal Pradesh, where colonies of approximately 100 individuals of both species were observed. Likewise, *R. ferrumequinum* has been categorised as Vulnerable on the basis of a restricted area of occupancy and a change in the quality of habitat. In Himachal Pradesh, though, this bat has been collected at many localities, albeit in small numbers.

Bats in India face a catastrophic loss of habitat, which decreases foraging areas, reduces prey populations, and often forces species to live in and around human habitations, making them more vulnerable (Mistry 2003). The quality of habitat for most of the bat species in this area is also deteriorating gradually. Stone-quarrying, for example, which is carried out in the state, is known to be detrimental to the existence of cave-dwelling bats (Murphy 1987). Caves in limestone areas may harbour healthy populations of many bat species. Large-scale mining of limestone is prevalent in Himachal Pradesh and poses a threat to the survival of many cave-dwelling bats. Although human population growth in Himachal Pradesh is not high, the rapid pace of urbanisation and industrialisation, especially in areas of lower elevation, is likely to have a severely detrimental impact on the region's bat fauna. As the urban landscape continues to encroach on rural areas, diversity and abundance of bat species in this region is likely to undergo a steady decline.

It is fortunate that other factors that are detrimental to bats, such as hunting for food, traditional medicine, and persecution, are almost non-existent in the state. Although fruit bats, notably *Pteropus giganteus*, cause considerable damage to fruit orchards, farmers are not normally hostile to their existence. It is to be hoped that this peaceful coexistence will continue for the time to come.

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Appendix 1. Geographical gazetteer of localities mentioned in the text

Arki 31°09′N & 76°57′E
Bakloh 32°27′N & 75°55′E
Ballu at Ghumarwin 31°26′N & 76°42′E
Bandrol c. 31°58′N & 77°07′E
Barotiwala 30°54′N & 76°51′E
Barog Tunnel 30°53′N & 77°05′E
Bhunter 31°52′N & 77°08′E
Bilaspur 31°20′N & 76°45′E
Brewery 30°55′N & 77°06′E
Chamba 32°33′N & 76°10′E
Chambaghat 30°55′N & 77°06′E
Chakmoh 31°27′N & 76° 32′E
Chatri 32°45′N & 76°12′E
Dadh 32°09′N & 76° 26′E
Dalhousie 32°32′N & 76°01′E
Damtal 32°12′N & 75°40′E
Dharamsala 32°14′N & 76°24′E
Dharampur 31°48′N & 76°45′E
Dodour near Nehr Chawk 31°35′N & 76°55′E
Drang c. 31°44′N & 76°55′E
Dunga Gali, Pakistan 34°03′N & 73°22′E
Gambhar 31°01′N & 76°58′E
Ghanatti 31°08′N & 77°05′E
Gopalpur 32°04′N & 76°16′E
Gutkar 31°39′N & 76°56′E
Happy Valley 30°53′N & 77°05′E
Hasimara, West Bengal c. 26°52′N & 89°48′E
Hissar, Haryana 29°10′N & 75°45′E
Kalatop 32°33′N & 76°01′E
Kangra 32°05′N & 76°15′E
Karool Hill 30°56′N & 77°05′E
Kasauli 30°54′N & 76°57′E
Keylong 32°34′N & 77°01′E
Kot Beja c. 30°53′N & 76°51′E
Kothi 32°13′N & 77°07′E
Kotla 31°43′N & 77°16′E
Kunihar 31°04′N & 76°57′E
Kullu 31°57′N & 77°06′E
Kullu valley c. 31°56′N & 77°01′E
Lutru cave 31°09′N & 76°57′E
Mahabaleshwar, Maharashtra 17°56′N & 73°42′E
Majothu 30°54′N & 76°51′E
Manali 32°12′N & 77°06′E
Mandi 31°43′N & 76°55′E
Manikaran c. 32°01′N & 77°20′E
Mansar lake, Jammu&Kashmir 32°48′N & 75°23′E
Mussoorie, Uttarakhand 30°26′N & 78°04′E
Nalagarh 31° 02′N & 76°43′E
Narkanda 31°15’N & 77°27’E
Nurpur 32° 17′ N & 75° 52′ E
Ratandi near Bagi c. 31°14′N & 77°32′E
Samayala 32°04′N & 76°16′E
Samar Hill near Madurai c. 09°55′N & 78°08′E
Shalaghat 31°11′N & 76°59′E
Shaur 32°54′N & 76°27′E
Shimla 31°06′N & 77°10′E
Shogran, Pakistan 34°37′N & 73°28′E
Simbalbara 30°28′N & 77°32′E
Sissu 32°32′N & 77°01′E
Sooma Not located
Solan 30°54′N & 77°05′E
Thirot c. 32°39′N & 76°46′E
Tottu 31°06′N & 77°07′E

Acknowledgements: The present work is an extension of a study on the small mammalian fauna of the Shiwaliks of Himachal Pradesh during the first author's stint as junior research fellow at ZSI, Solan. He is grateful to Dr. J.R.B. Alfred and Dr. Ramakrishna, former Directors, ZSI Kolkata; Dr. K. Venkataraman, Director, ZSI, Kolkata; Dr. A.K. Sanyal, Additional Director, ZSI, Kolkata; C. Radhakrishnan, Additional Director, ZSI, Calicut; Dr. K. Chandra, Additional Director, ZSI, Jabalpur; Dr. R.M. Sharma, former Officer-in-Charge, ZSI, Solan; Dr. A.K. Sidhu, Officer-in Charge, ZSI, Solan for institutional support and encouragement. US also expresses his gratitude to Dr. M.S. Pradhan, Retd. Scientist, ZSI, Pune and Dr. S.S. Talmale, ZSI, Jabalpur for imparting the basic knowledge of small mammalian taxonomy and literature support. Abhijit Das of Utkal University, Orissa and Narayan Sharma of NIAS, Bangalore provided suggestions for improvement on the earlier versions of the manuscript and literature support. Narayan Sharma also prepared the locality record map. Himachal Pradesh Forest Department is also thanked for permission to visit certain areas and manifold courtesies.

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